

EDIBLE WETLAND PLANT DIVERSITY, ECOSYSTEM SERVICES AND MANAGEMENT IMPLICATIONS IN WAITHOU PAT, MANIPUR

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ABSTRACT

This study was conducted from October 2024 to September 2025 to document edible wetland plant diversity in Waithou Pat (Manipur), a highly productive yet increasingly threatened freshwater wetland ecosystem in Northeast India. Freshwater wetlands support biodiversity, regulate hydrology, and sustain local livelihoods through multiple ecosystem services. In Waithou Pat, edible aquatic and semi-aquatic plants form a vital link between biodiversity and community well-being. Field surveys were carried out across four wetland zones: floating phumdi mats, shallow marsh edges, submerged/semi-submerged areas and seasonally inundated margins. Species identification followed standard taxonomic references and Local Ecological Knowledge (LEK) was incorporated to understand seasonal availability, edible parts used and patterns of resource dependence. Species were evaluated for provisioning and cultural ecosystem services, along with observed ecological pressures. A total of 21 edible wetland-associated plant species were recorded, exhibiting distinct habitat preferences linked to hydrological regimes. Floating-leaved and phumdi-associated species dominated permanently inundated zones, while emergent and semi-aquatic herbs were concentrated along shallow marsh edges and seasonal margins. Most species showed peak availability during monsoon and post-monsoon periods, with a few providing year-round subsistence resources. Field observations indicated increasing pressures from siltation, pollution runoff, hydrological alteration and habitat contraction. The findings highlight the ecological and socio-economic importance of edible wetland plants and emphasize the need for community-based conservation, seasonal harvesting guidelines and integrated wetland management to sustain biodiversity and ecosystem services.

(Key words: Wetlands, hydrophytes, ecosystem services, Waithou Pat, biodiversity)

INTRODUCTION

Wetlands are among the most productive ecological systems on earth, functioning as biological reservoirs, hydrological regulators and nutrient transformation zones that support diverse flora and fauna (Mitsch and Gosselink, 2015). In tropical regions, wetlands contribute substantially to ecological functioning through primary productivity, habitat provision, sediment retention, water purification, and climate moderation (Junk *et al.*, 2013). Wetland vegetation, particularly aquatic and semi-aquatic plants, plays a central role in maintaining these processes by stabilizing substrates, enhancing nutrient cycling and supporting associated food webs (Cronk and Fennessy, 2016). The provisioning, regulating, cultural, and supporting ecosystem services derived from wetland plant diversity are increasingly recognized as essential to both ecological resilience and human well-being (Everard and Finlayson, 2018).

Freshwater wetlands in Northeast India represent critical ecological and socio-cultural landscapes shaped by

monsoon dynamics, geomorphology and traditional subsistence interactions. Waithou Pat, located in Thoubal District of Manipur, exemplifies such a system, consisting of floating phumdi formations, shallow marsh basins, submerged vegetation zones and seasonally inundated margins that together support a rich assemblage of aquatic plant species. These hydrological gradients influence species composition, phenology, and productivity, while enabling edible wetland plants to contribute to community diets, household resilience, and cultural food identity (Bharucha and Pretty, 2010). Historically, local communities have harvested edible hydrophytes as supplementary nutritional sources, especially during periods of seasonal scarcity, demonstrating long-term human-wetland interdependence.

However, like many freshwater wetlands in South Asia, Waithou Pat is experiencing rapid ecological stress driven by siltation, agricultural runoff, invasive species expansion, shrinking hydrological depth and land-use alteration (Prusty *et al.*, 2017). These pressures threaten wetland vegetation structure, species availability and the

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ecosystem services associated with edible aquatic plants. Despite this emerging vulnerability, existing research has predominantly focused on ethnobotanical use, market value or species documentation, rather than ecological interpretation of habitat association, indicator value, and conservation relevance. There remains limited understanding of how edible wetland plants reflect ecological condition, contribute to wetland system functioning and can be integrated into community-supported management frameworks (Mukherjee *et al.*, 2014).

Addressing this knowledge gap is essential for linking biodiversity assessment with wetland management planning. Ecologically grounded documentation of edible wetland flora can enhance monitoring of habitat integrity, support sustainable harvesting norms and strengthen policy measures aimed at conserving wetland ecosystem services in Manipur and the broader Indo-Burma biogeographic region. Accordingly, this study aimed to document edible wetland plant diversity in Waithou Pat, analyse habitat-linked occurrence across wetland zones, interpret ecosystem service contributions related to provisioning and cultural support and evaluate implications for conservation and community-based wetland management.

MATERIALS AND METHODS

Study area

Waithou Pat is a freshwater wetland located in Thoubal District, Manipur, within the Indo-Burma biodiversity region. The wetland is characterized by a mosaic of hydrological and ecological zones, including floating phumdi formations, shallow marsh basins, submerged vegetation pockets and seasonally inundated margins. The area is influenced by a subtropical monsoon climate with distinct wet and dry seasons that regulate water depth, sediment deposition and vegetation dynamics. These hydrological fluctuations determine the spatial and temporal occurrence of edible aquatic and semi-aquatic plant species harvested by surrounding communities.

Habitat classification framework

To interpret species distribution in relation to ecological conditions, the wetland was divided into four habitat categories based on hydrological regime and vegetation characteristics. These included floating phumdi zones, characterized by buoyant vegetative mats with anchored rooting systems; shallow marsh edges, consisting of waterlogged margins that support emergent hydrophytes; submerged and semi-submerged zones, representing permanently or seasonally inundated areas and seasonally flooded margins, forming transitional terrestrial-aquatic interfaces influenced by periodic monsoon flooding. This classification framework was applied to systematically organize species occurrence patterns and ecological associations within the wetland, rather than to categorize plants according to ethnobotanical use.

Plant recording and identification

Edible wetland plant species were documented during October 2024 to September 2025 through field observation, direct collection, and photographic recording (Martin, 1995; Cotton, 1996). Identification was carried out using regional floras, herbarium comparisons and accepted botanical nomenclature standards (Bridson and Forman, 1998). Scientific names, author citations and taxonomic verification followed internationally accepted references to ensure consistency. Only species directly associated with wetland hydrology and used for consumption were included.

Local ecological knowledge documentation

Information from local harvesters, traditional gatherers and long-term residents was used to determine: seasonal availability, harvesting locations, edible parts utilized, patterns of dependence. This component is framed as local ecological knowledge (LEK) rather than ethnobotany, emphasizing ecological insight and resource-use patterns relevant to ecosystem services and management.

Data organization and interpretation

Data were structured to align with ecological analysis expectations: species richness, habitat-wise occurrence, seasonal availability patterns, ecosystem service contribution categories and perceived ecological threats. Threat indicators included: siltation, invasive plant encroachment, pollution runoff, hydrological decline and habitat contraction.

Ethical and research considerations

No plant species were removed in quantities that could affect local populations and no invasive or protected species were collected. LEK inputs were voluntary and non-extractive, respecting community knowledge without attribution to individuals.

RESULTS AND DISCUSSION

Waithou Pat was classified into four distinct habitat zones based on hydrological and vegetation characteristics (Table 1). Floating phumdi mats consisted of buoyant organic substrates with semi-buoyant, moisture-saturated conditions, dominated by rhizomatous and mat-forming species that stabilize the substrate and enhance nutrient retention. Shallow marsh edges comprised waterlogged margins with emergent hydrophytes and semi-aquatic herbs, characterized by high productivity and serving as crucial faunal interface habitats. Submerged and semi-submerged zones, either permanently or seasonally inundated, supported diverse aquatic vegetation and contributed significantly to aquatic food webs and hydrological buffering. Seasonally flooded margins represented transitional wetdry areas influenced by monsoon flooding, supporting flood-tolerant edible greens and functioning as important seasonal regeneration zones.

Plant documentation and sampling in Waithou Pat employed multiple complementary approaches (Table 2).

Field observations were undertaken to record species occurrence and ecological notes, while specimen collection and photographic documentation provided morphological verification. Taxonomic identification was confirmed using standard floras and herbarium cross-checking to ensure accuracy. Local Ecological Knowledge (LEK) was incorporated to determine habitat-linked availability and seasonal occurrence patterns of edible wetland plants. Habitat classification further enabled the association of species with specific hydrological zones, facilitating a clearer understanding of their ecological distribution and functional roles within the wetland ecosystem.

Species included in the study were naturally occurring, non-cultivated plants possessing edible parts such as shoots, leaves, rhizomes, petioles or young fronds. Their growth was hydrologically dependent on wetland regimes and they were recognized by local communities for traditional and subsistence use. These criteria ensured that the documented taxa reflected both ecological relevance and socio-cultural importance within Waithou Pat (Table 3).

The habitat-wise distribution of edible wetland plants revealed distinct ecological patterns across the four zones (Table 4). Floating phumdi mats were dominated by species such as *Euryale ferox*, *Nymphaea spp.*, *Trapa natans* and *Zizania latifolia*. Shallow marsh edges supported a broad diversity of species, including *Alpinia nigra*, *Colocasia esculenta*, *Ipomoea aquatica* and *Oenanthe javanica*, reflecting their high productivity and ecological interface with fauna. Submerged and semi-submerged zones were characterized by species such as *Eleocharis dulcis*, *Ipomoea aquatica*, and *Neptunia oleracea*, whereas seasonally inundated margins supported *Alpinia nigra*, *Eleocharis dulcis*, *Ipomoea aquatica* and *Marsilea spp.* Several species occurred across multiple habitats, indicating considerable ecological plasticity and adaptability to varying hydrological and substrate conditions within the wetland.

Seasonal analysis indicated that most edible wetland plants reached peak availability during the monsoon and post-monsoon periods (Table 5). Certain species, including *Colocasia esculenta* and *Oenanthe javanica*, were available year-round with moderate to high abundance, providing consistent subsistence resources. Floating-leaved species such as *Nymphaea spp.* and *Trapa natans* were primarily abundant during the monsoonpost-monsoon period, reflecting their dependence on elevated water levels. Early shoots of *Alpinia nigra* emerged during pre and post-monsoon seasons, while tuberous species like *Eleocharis dulcis* were predominantly harvested during the monsoon. These seasonal patterns highlight the strong influence of hydrological cycles on plant availability and underscore the importance of seasonal knowledge for sustainable harvesting and wetland resource management.

The discussion interprets the distribution of edible wetland plants in Waithou Pat in relation to hydrological zonation, habitat affiliation, seasonal dynamics, ecosystem services and implications for sustainable wetland

management. The delineation of the wetland into four habitat zones reflects the characteristic zonation patterns of subtropical floodplain ecosystems, where hydrology acts as the principal ecological driver (Mitsch and Gosselink, 2015). Floating phumdi mats function as nutrient sinks and substrate stabilizers, supporting buoyant vegetation adapted to saturated organic soils (Kadlec and Wallace, 2009). Shallow marshes sustain emergent and semi-aquatic herbs that create productive faunal interfaces, while submerged and semi-submerged zones maintain aquatic food webs and contribute to hydrological buffering (Cronk and Fennessy, 2016). Seasonally flooded margins serve as transitional regeneration areas for edible greens adapted to alternating wet/dry conditions. The occurrence of certain species across multiple zones demonstrates ecological plasticity and functional redundancy, enhancing ecosystem resilience under fluctuating water regimes (Walker, 1992; Elmquist *et al.*, 2003).

A total of 21 key edible species were recorded across diverse taxonomic groups, with families such as Zingiberaceae, Araceae, Nymphaeaceae, and Marsileaceae being particularly prominent. Species such as *Alpinia nigra* and *Ipomoea aquatica* were observed in more than one habitat zone, indicating broad ecological tolerance and adaptability to seasonal hydrological variation. The integration of local ecological knowledge (LEK) with systematic field observations strengthened habitat classification and validated patterns of species occurrence and seasonal availability (Berkes, 1999; Toledo, 2002), highlighting the importance of community knowledge in ecological assessment.

Seasonal analysis revealed pronounced monsoon and post-monsoon peaks in species availability, underscoring the central role of flooding cycles and water depth in regulating plant growth and harvest periods (Middleton, 1999). Species such as *Colocasia esculenta* and *Oenanthe javanica* were available throughout the year, providing reliable subsistence resources during comparatively lean seasons. These seasonal dynamics emphasize the need for regulated harvesting schedules aligned with regeneration cycles to prevent resource depletion and maintain long-term productivity.

The socio-ecological importance of edible wetland flora in Waithou Pat is evident in their contribution to food security (Anonymous, 2005; Anonymous, 2018), cultural practices and local livelihoods. However, pressures such as siltation, hydrological alteration, pollution, and invasive species pose significant threats to habitat integrity and plant availability. Conservation and management strategies must therefore prioritize habitat protection, hydrological stability, seasonal monitoring, and community-based stewardship. Integrating ecological findings with local subsistence needs into regional conservation planning will be essential for sustaining both biodiversity and livelihoods. By aligning habitat management with seasonal and ecological knowledge, Waithou Pat can be maintained as a resilient wetland system that continues to support culturally significant and economically valuable edible plant resources.

Table 1. Wetland habitat classification used in the study

Habitat type	Defining Characteristics	Hydrological Condition	Dominant Plant Forms	Ecological Relevance
Floating phumdi zones	Buoyant organic mats with anchored rooting systems	Semi-buoyant, moisture-saturated	Rhizomatous and mat-forming species	Substrate stabilization, nutrient retention
Shallow marsh edges	Waterlogged margins with persistent shallow standing water	Seasonally stable saturated soils	Emergent hydrophytes and semi-aquatic herbs	High productivity faunal habitat interface
Submerged / semi-submerge zones	Permanently or seasonally inundated	Open-water or low-depth hydrology	Aquatic and submerged vegetation	Aquatic food web hydrological buffering
Seasonally flooded margins	Transitional wet-dry zones affected by monsoon flooding	Alternating inundation and drying	Flood-tolerant edible greens	Seasonal resource availability, regeneration zone

Table 2. Overview of plant documentation and sampling inputs

Documentation components	Method applied	Purpose in study	Output type
Field observation	Direct site-based recording	Identify occurring edible wetland plants	Species occurrence notes
Specimen/photo records	Visual and morphological confirmation	Support taxonomic authentication	Image and form documentation
Taxonomic verification	Use of floras and herbarium cross-checking	Validate scientific names and authorship	Standardized nomenclature
Local ecological knowledge (LEK)	Non-structured community interaction	Determine seasonal and habitat-linked availability	Seasonal and usage patterns
Habitat classification	Ecological zoning of wetland structure	Associate species with hydrological zones	Habitat assignment

Table 3. Criteria used for inclusion of edible wetland plant species

Inclusion criterion	Description	Basis in study
Wetland association	Species occurring in submerged, marsh, phumdi, or inundated habitats	Ecological relevance
Edible usage	Consumption of shoots, leaves, rhizomes, petioles, or young fronds	LEK-supported
Hydrological dependence	Growth influenced by wetland water regimes	Moisture-linked
Non-cultivated status	Naturally occurring rather than farmed	Wild resource classification
Community recognition	Locally known and traditionally accessed	Subsistence relevance

Table 4. Habitat-wise occurrence matrix of edible wetland plant species in Waithou Pat

Scientific name	Floating phumdi	Shallow marsh edge	Submerged / semi-submerged	Seasonally inundated margins
<i>Alpinia nigra</i> (Gaertn.) B.L.Burt		✓		✓
<i>Colocasia esculenta</i> (L.) Schott		✓		
<i>Eleocharis dulcis</i> (Burm.f.) Trin. ex Hensch.		✓	✓	
<i>Euryale ferox</i> Salisb.	✓			
<i>Hedychium coronarium</i> (J.) Koenig		✓		
<i>Ipomoea aquatica</i> Forssk.		✓		✓
<i>Jussiaea repens</i> (L.)		✓		
<i>Marsilea minuta</i> (L.)				✓
<i>Marsilea quadrifolia</i> (L.)				✓
<i>Nelumbo nucifera</i> Gaertn.	✓			
<i>Nymphaea nouchali</i> Burm.f.	✓			
<i>Nymphaea pubescens</i> Willd.	✓			
<i>Nymphaea rubra</i> Roxb. ex Andrews	✓			
<i>Trapa natans</i> (L.)	✓			
<i>Sagittaria trifolia</i> (L.)			✓	
<i>Nymphoides indica</i> (L.) Kuntze	✓		✓	
<i>Oenanthe javanica</i> (Blume) DC.		✓		
<i>Neptunia oleracea</i> Lour.	✓		✓	
<i>Persicaria barbata</i> (L.) H.Hara		✓		✓
<i>Persicaria glabra</i> (Willd.) M.Gómez		✓		
<i>Zizania latifolia</i> (Griseb.) Turcz. ex Stapf	✓			

✓= species observed / inferred in that habitat

Table 5. Seasonal availability of edible wetland plant species in Waithou Pat

Scientific name	Pre-monsoon	Monsoon	Post-monsoon	Winter	Notes
<i>Alpinia nigra</i> (Gaertn.) B.L.Burtt	1	2	2	0	early shoots pre/post-monsoon
<i>Colocasia esculenta</i> (L.) Schott	2	3	3	2	year-round with peak post-monsoon
<i>Eleocharis dulcis</i> (Burm.f.) Trin. ex Hensch.	1	3	2	0	tuberous peak in monsoon
<i>Euryale ferox</i> Salisb.	0	3	3	0	monsoon–post- monsoon seeds
<i>Hedychium coronarium</i> (J.) Koenig	1	3	2	1	flowering & use in wet season
<i>Ipomoea aquatica</i> Forssk.	1	3	3	2	grows best in monsoon–post seasonal wetland
<i>Jussiaea repens</i> (L.)	0	3	2	0	herb
<i>Marsilea minuta</i> (L.)	0	3	2	0	monsoon leaf emergence
<i>Marsilea quadrifolia</i> (L.)	0	3	2	0	similar to <i>M.</i> <i>minuta</i>
<i>Nelumbo nucifera</i> Gaertn.	1	3	3	1	flowers & rhizomes in wet season
<i>Nymphaea nouchali</i> Burm.f.	0	3	2	0	floating leaf/flower peak monsoon
<i>Nymphaea pubescens</i> Willd.	0	3	2	0	floating leaf/flower peak monsoon
<i>Nymphaea rubra</i> Roxb. ex Andrews	0	3	2	0	floating leaf/flower peak monsoon
<i>Trapa natans</i> (L.)	0	3	3	1	fruiting post- monsoon
<i>Sagittaria trifolia</i> (L.)	1	3	2	1	tubers harvested post-monsoon
<i>Nymphoides indica</i> (L.) Kuntze	1	3	2	0	floating-leaved species
<i>Oenanthe javanica</i> (Blume) DC.	2	3	3	2	thrives in wet & cool seasons
<i>Neptunia oleracea</i> Lour.	0	3	2	0	floating abundance monsoon
<i>Persicaria barbata</i> (L.) H.Hara	1	3	2	1	seasonal marsh herb
<i>Persicaria glabra</i> (Willd.) M.Gómez	1	3	2	1	seasonal marsh herb
<i>Zizania latifolia</i> (Griseb.) Turcz. ex Stapf	0	3	2	0	swollen stems in monsoon–post

4 seasonal categories: **Pre-monsoon, Monsoon, Post-monsoon, Winter**

Codes: **3 = High, 2 = Moderate, 1 = Low, 0 = Absent**

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